

APPENDIX C:
Salmon Creek and Okanogan Irrigation District
Water System Model

Appendix C -- SALMON CREEK AND OID WATER SYSTEM MODEL

INTRODUCTION

A water supply model was developed as part of the Phase I Joint Study on Salmon Creek (Dames & Moore, 1999) to simulate the current operations of the Salmon Creek and OID water supply systems and to quantify how much additional water could be provided by various water supply alternatives. The model is described in detail in Section 3.0 of the Dames & Moore (1999) report. For the EIS, this model was updated and used again to examine water quantity differences among the four EIS alternatives. This appendix is a revision of Section 3.0 of the 1999 report.

Phase I Study Scope and Objectives

For the Phase I Study, the scope and objectives of the water system model included:

- Determine quality and extent of existing hydrological data as a basis for modeling.
- Create a reasonably complete data set for modeling. Include all available data and significant drought periods, particularly the 1930's drought period. Fill in and extrapolate from the record as required.
- Define long-term hydrological data sets for the water system model.
- Develop a system and reservoir operations model to evaluate the water supply yield and reliability of the existing water supply system for OID, and integrate instream flow requirements for anadromous salmonids.
- Determine how the existing irrigation system operates under existing water sources and demands.
- Evaluate daily and weekly flow releases to Salmon Creek and daily irrigation schedules in OID to the extent data allow.
- Assess upper watershed yield to assess the raising of Salmon Lake Dam.
- Evaluate the availability of water supply for instream flows in lower Salmon Creek, to evaluate the feasibility of meeting both OID irrigation demands and instream flows with various supplemental sources and physical improvements to the system.

The model used historical runoff data from the Salmon Creek watershed for the period 1904-1998 to simulate the operations of Conconully and Salmon Lake reservoirs, the OID irrigation withdrawals from Salmon Creek, input parameters per various water supply alternatives, and the resulting amount of instream flow in Salmon Creek. The model incorporated the complexity of

the OID irrigation supply system, which obtains its water from three separate sources (Salmon Creek, Johnson Creek/Duck Lake, and the Okanogan River).

EIS Scope and Objectives

Although a number of water-system model runs were conducted as part of the Phase I Study to evaluate various water supply and water conservation options, additional water system model runs were necessary to assess impacts from the four alternatives. However, no new water system model subroutines were created for the EIS analyses. Minor revisions were made to certain components of the model. The revisions included 1) updating the model structure and simulation through to 2002 (i.e., adding four more years of input data including streamflow, reservoir storage, and OID usage data), 2) reviewing and revising crop water requirements and OID irrigation demands, 3) reviewing and revising the model's approach at delivery efficiency and the resultant monthly distribution of canal spill to Duck Lake, and 4) adding the instream flow requirements associated with each scenario (i.e., providing flows for steelhead only with channel rehabilitation, steelhead and chinook with channel rehabilitation, and steelhead only without channel rehabilitation).

At the outset, an attempt was made to structure each water system model alternative to address the EIS target water volume of 5100 ac-ft/year. Combinations of water supply alternatives were not modeled. The feeder canal upgrade was included with each water supply alternative. Unrestricted pumping was assumed for diversions from the Okanogan River under action alternatives 1 and 2 (no minimum flow restrictions are assumed on the Okanogan River).

Documentation for the water system model is provided in the sections below and in Appendix 3.1-E. While these model descriptions are extensive, they do not completely describe all aspects of the model. A user's manual describing all input, assumptions, calculations, and capabilities of the model was not prepared as part of Phase I scope of work or for this EIS.

WATER SUPPLY FIRM YIELD

Purpose and Accuracy of Model

The water supply model was used to:

- estimate how much water for instream flow could be obtained on a firm annual basis from each of the alternatives; and
- simulate the existing OID irrigation system to determine what quantity of Salmon Creek water is needed by OID and to verify that new water supplies would not adversely affect OID's firm irrigation supply.

The modeling of current irrigation operations was based on the OID Manager's descriptions of how the system is operated, on matching recent operations, and on insights gained from the modeling into which operational strategies resulted in the greatest firm yield from Salmon Creek.

The model accurately describes the magnitude and variability of OID irrigation demand, and the ability to supply that demand from Salmon Creek and the Duck Lake and Shellrock pumping stations. It was generally observed that the model could duplicate the operational patterns of OID in terms of average irrigation water supply and the magnitudes of pumping by Shellrock and Duck Lake. However, exact replications of recent yearly irrigation operations are less precise because all behaviors of the OID operators and farmers, and unpredictable events such as pump breakdowns, cannot be simulated by the model.

Although the model is capable of mimicking the irrigation system under many different potential operating rules and methods, further evaluation of the OID system with possible additional model refinements could be made.

Definition of Firm Water Supply for Irrigation and Instream Flow

For a water supply source to be considered firm, the water supply model must show that it could provide a dependable supply of water during all years in the 1904-2002 simulation period. The sequence of years with the lowest streamflow magnitudes (termed the critical period) is the drought period that extended from the late 1920s to the early 1930s. This drought period was at its worst in 1931, when only 1,500 acre-feet of runoff was measured in the Salmon Creek watershed (compared to the 99-year average of 21,600 acre-feet/year). The period when Conconully and Salmon Lake reservoirs did not fill, as predicted by modeling, lasted over ten years (from 1924 to 1934).

Thus, to be considered a “firm” supply, water for irrigation and instream flows must be provided in full in each year to meet the required water demand through the 1920-30s drought period. The model shows that under current operations the total reservoir storage would have become totally depleted at the end of the 1931 irrigation season. To get through a year like 1931, pumping from the Okanogan River would have to occur at a level equal to the full nominal capacity of Shellrock.

The analysis of firm capacity assumes a 22 percent channel seepage loss in the lower reach of the Salmon Creek channel, and applies this percent loss as a constant across all flows. This estimated loss is almost certainly conservative, as it is based on the observed losses that were measured during a single, short controlled release test conducted for the Phase I Study. The test was conducted before the spring freshet may have fully recharged the groundwater table, and did not consider the likelihood that such loss, expressed as a percent, is likely to vary with flow. Therefore, firm yields are probably understated.

WATER SUPPLY MODEL OVERVIEW

Overview

The water supply model for the Salmon Creek watershed and OID irrigation system is a monthly water balance model that uses historical monthly Salmon Creek flows in a reservoir operation, irrigation demand, and instream flow demand simulation. The model was created using an Excel spreadsheet that contains 131 columns of water balance calculations for each month of the 99-year simulation period (i.e., 1,188 rows). Overall, the Excel file is about 12 Mbytes in size and requires a minimum of a 133 MHz Pentium computer to operate efficiently. A schematic of the water supply model is shown in the 1999 Phase 1 Report (Dames & Moore, 1999)

A summary of the model components is provided in Attachment Table C-1. This table summarizes the input data for the model, explains the rules that define how irrigation supply, irrigation demand, and instream flow releases are determined, and identifies model components that can be modified to evaluate different irrigation and instream flow operations. Attachment Table C-2 summarizes how sources of water for irrigation supply and irrigation demand are prioritized in the model. Attachment Table C-3 is a listing of the spreadsheet calculation parameters and definitions. The attachment tables have not been modified from the Phase I report (Dames & Moore, 1999).

Historical Salmon Creek watershed runoff is input as a 99-year time series file of historic monthly watershed runoff (in acre-feet per month). This total is then split into the West, North, South, and Salmon Lake forks of Salmon Creek based on proportions developed from the drainage area and average elevation of each sub-watershed. These flows enter the reservoir system of Salmon Lake and Conconully reservoirs, with flow to Salmon Lake regulated by the capacity of the feeder canal. Water is released from the reservoirs based on demand for irrigation supply and instream flow, middle reach local inflow or seepage loss, and other operational criteria.

A separate water balance within the model represents the Duck Lake water storage system. This water balance includes canal spill, Johnson Creek diversion, groundwater seepage (and to a lesser extent evaporation loss), OID groundwater sale, and Duck Lake pumping. Parameters for the Duck Lake water balance, such as the estimated magnitude of seepage loss from the Duck Lake basin, are based on a separate water balance model conducted using the 1987-1998 data set of monthly inflows (canal spill and Johnson Creek), outflows (Duck Lake pumping), and lake elevations, as described in the Phase I report (Dames & Moore, 1999).

The total irrigation requirement determines the amount of water needed for irrigation delivery to OID farmers. The model makes initial assumptions of the magnitudes of supply from the Salmon Creek diversion (including additional for conveyance and spill loss), Duck Lake pumping, and Shellrock pumping. This initial assumption is primarily based on historical pumping rates for Shellrock. Pumping flows from Duck Lake are initially set at a relatively low rate for the No Action Alternative; little operating flexibility exists for Duck Lake because

inflow is restricted to a relatively narrow range, and little storage exists in the lake. As a result, Duck Lake basically operates according to how much water is available each year.

The model simulation then adjusts the pumping and Salmon Creek diversion rates according to how much storage is available in the reservoirs, and whether spill occurs from Conconully Reservoir. During low reservoir storage conditions, Shellrock can be directed to operate at maximum pumping rates (as specified by a critical reservoir storage volume) to provide supplemental supply during drought periods. At the other extreme, when spill occurs, pumping is cut back and diversion from the creek is increased to the extent possible (subject to instream flow requirements). Optionally, greater pumping can be specified during warm years and less during cool years.

Streamflows in Salmon Creek are tracked from Conconully Dam to the mouth. On the middle reach, local inflow or loss is added or subtracted from the streamflow. On the lower reach channel losses are subtracted from the streamflow. Loss rates were estimated from flow data collected during the three-day controlled release study during Phase 1. Total loss in the lower reach during that study ranged from 14 percent to 31 percent. A total loss of 22 percent was assumed in the operational studies, as follows: lower reach stream flow losses were conservatively established at 6 percent of flow between the diversion dam and the springs, and 16 percent between the springs and the mouth of Salmon Creek. However, the actual loss is likely to approach a constant volume, rather than increase as a percentage of flow. The stream channel loss may also diminish to a smaller constant amount if the groundwater table is recharged once flows are provided to the lower reach. Therefore, this assumption of stream loss may result in a significant underestimate of instream flow volumes and benefits. Further field studies are recommended to resolve stream channel loss volumes.

Streamflows were evaluated at four streamflow assessment points: immediately upstream of the diversion dam (i.e., the lowest point of the Middle Reach), immediately below the diversion (i.e., flow over the Salmon Creek weir), immediately below Watercress Springs, and at the mouth of Salmon Creek.

The effects of OID pumping at Shellrock and under other alternatives, as well as changes in Salmon Creek discharges, are also tracked on the Okanogan River. Starting with the river flows above Shellrock, pumping flows are subtracted from the Okanogan River at Shellrock (and/or the new pumping station) and added at the mouth of Salmon Creek. This means the changes in Okanogan River flows, as compared to modeled existing conditions, can be determined at the three streamflow assessment points.

Instream flow for the middle and lower reaches of Salmon Creek is specified as a reservoir demand, similar to irrigation demand. . In specifying instream flow releases from the reservoir, flow gains or losses in the middle and lower reaches are accounted for. Also, no instream flow release occurs during reservoir spill because water is being released anyway.

Data Sources

Data used to develop time series input data and operational parameters for the water supply model are described below.

Okanogan Irrigation District

Data provided by OID included:

- Recent irrigation operations data, including monthly diversions from Salmon Creek, spill to Duck Lake, Johnson Creek diversion, Duck Lake and Shellrock pumping, and Duck Lake elevations for 1987-2002, and middle reach gain and loss data for four years. OID compiled and verified the accuracy of the 1987-2002 operations data (Paul Frazier, personal communication, June 7, 1999, with supplemental data from Tom Sullivan, personal communication, June 23, 2003).
- Recent (1999-2002) historical Conconully and Salmon Lake reservoir operation data, including monthly storage, and inflow and outflows (Tom Sullivan, personal communication, June 23, 2003).
- Miscellaneous historical operations data provided to the Phase I study team during the project kickoff meeting, held in Okanogan on February 1 and 2, 1999.
- Verbal descriptions of operations, as conveyed during work sessions and several telephone conversations.
- Draft Conservation and Management Plan, describing the current irrigation system facilities (OID 1998).

Bureau of Reclamation

Data provided by the Bureau of Reclamation included:

- Historical Conconully and Salmon Lake reservoir operation data, including monthly storage, inflow and outflows, which are stored on USBR computers in Boise, Idaho (J. . Doty, personal communication, March 9, 1999).
- OID provided a 1968 USBR operations study that documented the only source of Salmon Creek streamflow data for the period 1904-1946 (USBR 1968).
- OID provided the USBR Conconully and Salmon Lake dam Standard Operating Procedures manuals that contains data on the physical characteristics of the reservoirs (USBR 1989a, b).
- OID provided USBR Okanogan Project Water Supply Reports (i.e., monthly reservoir data) for 1973-1999.

National Oceanographic and Atmospheric Administration

Data obtained from NOAA included historical Omak and Conconully temperature and precipitation, available on the Internet and climatological publications.

U.S. Geological Survey

Data obtained from USGS included the following historical streamflow data:

- Okanogan River at Tonasket (No. 12445000, 1911-2002)
- Okanogan River at Malott (No. 12447200, 1966-2002)
- Okanogan River near Malott (No. 12447300, 1958-1967)
- Other streamflow data for regional streams, intended to be used to estimate Johnson Creek flows and Salmon Creek middle reach flows. However, no historical data could be located to estimate Johnson Creek runoff. For Salmon Creek, OID dam release and diversion records for four recent years were used to estimate middle reach inflow or loss.

Model Input Data

Model data is input into the water supply model on worksheets within the Excel file. These worksheets (which are multiple spreadsheets within a single Excel file) are described below:

General Input

General input include reservoir sizes, pumping capacities, Duck Lake groundwater pumping, and other facilities for existing and new facilities. Shaded cells in the worksheet indicate where user-defined model parameters may be modified (such as the capacity of Salmon Lake reservoir) in modeling irrigation operations for the various alternatives.

Input Time Series

Input time series include monthly flows for Salmon Creek and Okanogan River for the 1904-2002 simulation period, yearly climate data including precipitation, and yearly middle reach gain and losses. These data are not changed during model simulations.

Salmon Creek and Okanogan River flow data are based on historical records (See section below describing Salmon Creek, Okanogan River and climate data). Calculations are performed in the spreadsheet to determine Okanogan River flows at points upstream of the gauging station, based on Salmon Creek and Shellrock pumping flows that were estimated by the existing conditions model run. These three sets of Okanogan River flows – above Shellrock, between Shellrock and Salmon Creek, and below Salmon Creek – were produced and used to evaluate potential changes in Okanogan River flows under the alternatives due to increased pumping or a changed flow regime in Salmon Creek.

Annual temperature, precipitation, and middle reach gain/loss time series are also included. Omak mean summer temperatures, calculated by giving June a weight of 50 percent and July and August weights of 100 percent, are used to estimate annual total irrigation demands. Omak water year (October-September) precipitation is used to estimate Johnson Creek diversion flows because a correlation analysis determined that Johnson Creek diversion flow is best estimated by annual precipitation. Precipitation was used to estimate Johnson Creek flow because no historical data other than monthly OID diversion flows from Johnson Creek could be located for the Johnson Creek watershed.

The middle reach gain/loss time series is based on measured data provided by OID for 1988, 1989, 1997 and 1998. From these data, maximum gains and losses in the middle reach were determined. Correlation analyses indicated that total annual gains and losses are best estimated by the Omak March-July precipitation; a lookup function is used in the model to estimate annual gain or loss, and is then converted to monthly time series based on a fixed annual distribution. Winter seepage flows of 100 acre-feet/month (as determined from USBR Water Supply Report data) were then added to the gain/loss values to account for seepage from the dam during the non-irrigation season.

Irrigation Demand

Details on the total irrigation demand during warm and cool years are specified in the model. Based on OID data, a good correlation between mean Omak summer temperature and total irrigation delivery was found. Irrigation demand is specified in terms of an annual crop irrigation requirement and the on-farm efficiency. The annual irrigation demand is then distributed into April-October monthly demands based on percentages calculated from the 1987-2002 historical operations data.

Shellrock and Duck Lake operations parameters are also specified under irrigation demand. This includes pumping rates under average conditions (so that less pumping occurs in early and late season months, in proportion to total demand), the critical reservoir storage capacity at which pumping should be increased to maximum, and whether pumping is subject to instream flow limitation in the Okanogan River. For Duck Lake, maximum and minimum reservoir elevations are also specified. Also, it can be specified whether Shellrock pumping is to be stopped for the remainder of the year if reservoir spill occurs, which appears to be the current OID practice. Model sensitivity analyses confirmed that this is a good operational strategy because very little additional firm yield is obtained if Shellrock pumping is maximized in the months following reservoir spill (e.g., during July through September if spill stops in June).

District and On-Farm Efficiencies

Based on analysis of the crop census provided by OID, daily crop water requirements, and water delivery to farms and spills, existing irrigation efficiencies were determined. Percent efficiency for each measure was calculated based on the following formula:

$$\text{percent On-Farm Efficiency} = (\text{Total Crop Water Requirement}) / (\text{Total Delivery to the Farms})$$

$$\text{percent District Efficiency} = (\text{Total Delivery to the Farms}) / (\text{End of canal Spills} + \text{Total Delivery to the Farms})$$

$$\text{percent Overall Efficiency} = \text{percent Farm Efficiency} \times \text{percent District Efficiency}$$

Based on these formulas it was concluded during the Phase I Study that the district efficiency was remarkably consistent across the period, averaging about 86% per year. The main factor affecting the district efficiency was spill and main canal losses. Further, on-farm efficiency appeared to be a function of water year type. In dry or water short years (i.e. 1993, 1994) farmers apply water conservatively and efficiencies exceeding 100 percent (i.e., deficit watering) were achieved. In wet years (i.e. 1998) water was liberally applied and annual efficiencies dropped to as low as 66 percent. Over all years in the period, on-farm efficiencies averaged 82 percent. The overall district efficiency, considering both district-wide and on-farm efficiencies, averaged 70 percent and ranged from 57 percent to 84 percent for the period. As compared to other irrigation districts in the region OID achieves a relatively high efficiency.

The Phase 1 iteration of the model assumed a constant canal spill of 13.4% plus an additional canal loss increment of 0.4% to reflect the overall 86% average efficiency. However, in our review of updated OID data for developing model input parameters, we determined that OID's management of canal spill was not constant during the year but was more a function of season, in that they were much more efficient during the summer months (i.e., when conveying large volumes of water) and less efficient during the non-irrigation season (Table C-1). Thus, the model rules were revised so that actual efficiencies were expressed by distributing canal spills according to OID's historical management practices shown in Table C-1.

Table C-1. 1987-2002 average OID monthly demand and distribution of water.

	<i>Average Monthly Demand From Salmon Creek, Okanogan River and Duck Lake (ac-ft)</i>	<i>Average Distribution of OID Delivery to Farms</i>	<i>Average Proportion of OID Canal Water Spilled to Duck Lake</i>
Jan	5	0.0%	1.7%
Feb	8	0.0%	3.2%
Mar	90	0.1%	21.8%
Apr	705	2.8%	34.2%
May	2547	14.1%	14.4%
Jun	3002	16.8%	13.5%
Jul	3848	22.6%	9.5%
Aug	3938	23.6%	8.0%
Sep	2955	17.5%	8.9%
Oct	510	2.4%	28.9%
Nov	80	0.1%	26.7%
Dec	31	0.0%	19.0%

Instream Flow Demand

Instream flow demand is the amount of water that must be released from Conconully and Salmon Lake reservoirs to meet required monthly instream flow rates. Instream flow demand is specified as one of the three flow scenarios described in the description of alternatives (Section 2.0). Separate flows are specified for the middle reach and the lower reach. It is assumed that flows in both reaches would be provided to satisfy instream flow requirements as specified in Tables C-2 and C-3.

Table C2. Middle Reach Salmon Creek: recommended minimum flows for fish *

	<i>Monthly Volume acre-feet)</i>	<i>Monthly Volume (acre-feet)</i>	<i>Monthly Volume (acre-feet)</i>
Species	Steelhead Only	Chinook Only	Steelhead & Chinook
Jan	246	430	430
Feb	222	388	388
Mar	246	430	430
Apr	891	416	891
May	921	1,228	1,228
Jun	891	1,188	1,188
Jul	614	1,228	1,228
Aug	614	1,228	1,228
Sep	594	416	594
Oct	246	430	430
Nov	238	416	416
Dec	246	430	430
Annual Sum	5,966	8,225	8,878

*a) The minimum instream flows for the Middle Reach include 'new' water needs in addition to irrigation conveyance through the reach. They are instream flow requirements.

*b) Minimum flows may be provided as part of seasonal irrigation conveyance (included within irrigation demand), or they are a 'new' water need when the irrigation conveyance in the middle reach does not equal or exceed these values.

*c) New water is needed in the Middle Reach for instream minimum flows in non-irrigation season months for all action alternatives.

*d) In some alternatives, new water is needed in the Middle Reach if irrigation conveyance is reduced.

Table C-3. Lower Reach Salmon Creek: recommended minimum flows for fish (passage only)*

	<i>Monthly Volume (acre-feet)</i>	<i>Monthly Volume (acre-feet)</i>	<i>Monthly Volume (acre-feet)</i>	<i>Monthly Volume (acre-feet)</i>
Lower Reach Rehab?	No	Yes	Yes	Yes
Species	Steelhead Only	Steelhead Only	Chinook Only	Steelhead & Chinook
Jan	-	-	-	-
Feb	-	-	-	-
Mar	495	356	-	356
Apr	1,337	891	-	891
May	812	812	1,228	1,287
Jun	-	-	1,188	1,188
Jul	-	-	594	594
Aug	-	-	-	-
Sep	-	-	-	-
Oct	-	-	-	-
Nov	-	-	-	-
Dec	-	-	-	-
<i>Annual Sum</i>	2,643	2,059	3,010	4,316

*a) The minimum instream flows for the Lower Reach represent 'new' water needed in addition to irrigation demand. It is possible that passage minimums during May or June may be met through spill in some years

*b) Additional water may occur in the Lower Reach from larger spills, and flows in the lower reach may be increased during 'non-irrigation' season months by minimum flows required in the Middle Reach that continue downstream of the OID diversion dam.

For the middle reach, no instream flow demand is placed on the reservoir if irrigation water is released; reservoir spill and/or local inflow already provide the flow. For the lower reach, since irrigation water is not conveyed in that reach, releases are to serve instream flow demand only (except during reservoir spill, which is not counted as an instream flow release). Channel seepage losses are added to the lower reach instream flow rates; therefore, the instream flow demand for the lower reach is adjusted to account for seepage losses.

Tables C-2 and C-3 summarize the three instream flow scenarios analyzed (*Chinook Only* was not analyzed per se as it has the same flow requirements as *Steelhead and Chinook*), the required amounts of water needed on a monthly basis for the middle and lower reaches, and the total amount of water needed for both reaches. The difference between the instream flow release at the diversion dam and the instream flow at the mouth of Salmon Creek is the quantity of channel seepage loss assumed for the lower reach. Since reservoir spill and local inflow will provide a portion of these instream flows, the actual average instream flow release at the diversion dam will be somewhat smaller.

Model Output

Model output consists of the following:

- A two-page run summary (first worksheet page in Excel file)

- Three pages of graphs showing annual Salmon Creek streamflows, irrigation water sources (pumping and diversions), and reservoir storages.
- Detailed listings of 99-years of monthly or annual spreadsheet calculations; normally only the annual summary is printed (eight pages for the annual summary versus 112 pages for the detailed monthly listing).

SALMON CREEK, OKANOGAN RIVER, AND CLIMATE DATA

Historical Salmon Creek Watershed Runoff

Historical watershed runoff for Salmon Creek is defined as the amount of runoff entering Conconully and Salmon Lake reservoirs. These data were calculated from monthly historical reservoir operations data recorded by the Bureau of Reclamation. Since these data already include the effects of historical reservoir evaporation, the model did not have to modify the inflow data to factor in evaporation losses.

Historical Flow Data

Annual and monthly historical runoff for the Salmon Creek watershed is provided in Appendices B-3, and shown graphically in Figures 3.1-4 and 3.1-5. Total watershed runoff is quantified in terms of acre-feet in Figure 3.1-4. Over the 99-year record, calendar year annual runoff varied between 1,500 in 1931 and 67,000 in 1983, with a mean of 21,635 acre-feet/year. The line showing the five-year moving average indicates that watershed runoff follows a clear pattern of multi-year wet and dry period cycles. Since Conconully and Salmon Lake reservoirs can hold only 1.47 years of irrigation water, the OID water supply is very susceptible to runoff conditions during occasional, but dramatic, dry cycles. During wet cycles most of the excess runoff is spilled.

Historical Reservoir Data

Appendix B-2 contains Conconully and Salmon Lake reservoir storage, inflow and outflow data. Plots of historical reservoir inflow and outflow, and storage utilization are shown in Figures 3.1-11 and 3.1-12 for the period 1947-1996 (these data are not available for years prior to 1947). The storage utilization plots show how much of the reservoir is used during each year: for catching the spring runoff for release during the April-October irrigation season. A large part of the storage in the reservoirs is used just to store the water needed during the current year; only that portion of storage remaining after the end of the irrigation season is available for carry-over to the next year. The minimum storage during the 1947-1998 period occurred in 1966; it was particularly depressed that year due to two consecutive dry years and because Conconully was completely drained in 1965 for outlet maintenance.

Figures 3.1-11 and 3.1-12 show the utilization of active storage in Conconully and Salmon Lake Reservoirs. Storage utilization is the water used during the year for capturing spring runoff for subsequent release for irrigation. This graph shows that Conconully Reservoir is drawn down

much more frequently and with greater magnitude than Salmon Lake reservoir. In fact, in many years the storage in Salmon Lake reservoir is not utilized at all. This is because the feeder canal places a restriction on how quickly the reservoir can be filled. Thus, OID usually relies more on Conconully reservoir for irrigation release, and less upon Salmon Lake reservoir.

Salmon Creek Flow Exceedance

A flow exceedance shows, on a monthly basis, the percentage of years that streamflows historically have occurred at different flow magnitudes. The median flow is the same as the 50 percent exceedance, a one-in-ten year low flow is the same as the 90 percent exceedance (i.e., exceeded 90 percent of the time, or nine years out of ten), and the one-in-ten year high flow is the same as the 10 percent exceedance (i.e., exceeded only 10 percent of the time, or one year in ten).

Flow exceedances for Salmon Creek watershed runoff at Conconully Dam are shown in Figure 3.1-5. The data used to produce this graph are tabulated in Appendix B-3, and have been adjusted for historical evaporation loss (equal to about 1,600 acre-feet per year) to make the low-flow estimates more accurate. During the one-in-ten dry year, the natural flow of Salmon Creek falls to a minimum of about 2 cfs in September; during median flow years it is about 8 cfs. No data were available to estimate the magnitude of historic natural flows in lower Salmon Creek, which may be affected by seepage loss and/or gains from springs.

Streamflows in Salmon Creek below Conconully Dam are dramatically affected by two factors: the impoundment of spring runoff and the irrigation release schedule later in the spring and summer. As shown in Figure 3.1-5, stream flows in the middle reach occur almost exclusively during the months of April through September, the irrigation release period. During the remainder of the year, flow in the stream is limited to that seeping from the dam and local inflow entering the stream below the dam. Seepage from the dam is on the order of 100 acre-feet per month (based on data from a USBR Water Supply Report), or about 1.6 cfs. Available information is not reliable to estimate the magnitude of local inflow to the middle reach during the winter.

In the lower reach of Salmon Creek (see Figure 3.1-6), streamflow is limited to the occasional reservoir spill (occurring less than 50 percent of the time during the months of April, May, and June). The stream is essentially dry the remaining months, except possibly during wet years and occasional rainfall runoff events. Prior to 1996, no data are available on timing or magnitude of lower Salmon Creek flows; however, in that year a weir was installed on the OID main canal to allow measurement of flows passing the diversion.

Calculation of Watershed Runoff

OID personnel collect data on reservoir elevations and discharges daily; after conversion to monthly data, they are transmitted to the Bureau of Reclamation for documentation and archiving purposes. With the exception of the past several years, OID has not retained past records of reservoir operations in their offices.

Watershed runoff is calculated using the following equation:

$$\text{Monthly watershed runoff} = \text{Conconully outflow} + \text{gain in total reservoir storage during month.}$$

This equation provides a good estimate of total runoff over consecutive months, but for individual months it may not be precise because reservoir storage data are based on lake elevation readings, which do not give precise readings of total storage. For example, a 0.1-foot measurement error in the Conconully Reservoir elevation reading corresponds to a 50 acre-feet error in storage. Thus, a measurement that is not carefully read, or is affected by wave run-up due to wind, can be off by several hundred acre-feet. During low-flow months this can result in negative inflow readings. Evaporation and seepage loss can also add to a negative estimate of reservoir inflow if no storage is released. However, lack of precision for low flows is not an issue because the data are used for multi-year reservoir simulation, and precision errors cancel each other out during a relatively short period.

Other possible sources of error in the Salmon Creek watershed runoff data include measurement error in the weir below the dam (particularly when water flows over the spillway, resulting in poor flow estimates), calculation errors in converting daily data to monthly data, and data transcription errors when the Bureau of Reclamation entered data into their computer system. Original dam records were not available for data checking to verify records of historical data.

Historical Okanogan River Streamflows

Historical streamflow data for the Okanogan River were obtained from USGS gauging records. Records are available for the Malott gauge (located a short distance downstream of the City of Okanogan) for the period of 1958-2002. Prior to that, flow data from the Tonasket gauge (located a considerable distance upstream of Okanogan) for the period 1911-2002 were used. By comparing the overlapping periods of Malott and Tonasket gauging, it was found that Malott flows are approximately 4 percent higher than Tonasket flows. Thus, Tonasket gauging records for the period 1911-1957 were multiplied by 1.04 to represent the flows at Malott prior to 1958.

Historical Flow Data

Annual historical runoff for the Okanogan River watershed is shown in Figure 3.1-2. Appendix B-1 contains the monthly historical flow record for the Okanogan River. The average annual runoff in the Okanogan River is 2,193,000 acre-feet (water year), and has varied historically between a minimum of 860,000 acre-feet in 1931 to a maximum of 4,600,000 acre-feet in 1972.

When compared to annual Salmon Creek watershed runoff (Figure 3.1-4), the Okanogan River exhibits much less variation between the wet and dry cycles. The flow in the Okanogan River drops sharply only during extended dry periods such as the 1930s drought. The minimum annual flow occurred in 1931, when it fell to 39 percent of average. By comparison, Salmon Creek runoff in 1931 fell to just 7 percent of average.

Climate Data

As noted above, climatic data are used in the water supply model to estimate annual irrigation demand, streamflow in the middle reach of Salmon Creek, and annual Johnson Creek irrigation diversions. Climate data was reported in the Dames & Moore (1999) Phase I report; Appendix Tables 3B-12, 3B-13 and 3B-14 contain historical Omak monthly temperatures (1910-1998), Omak monthly precipitation (1904-1980), and Conconully monthly precipitation (1975-1998), respectively. Updated data through 2002 were available from the National Climate Data Center.

HISTORICAL OID WATER USE

Historic Operations Data

Drawing upon available district records, OID compiled historical water supply and use data for the period from 1987 to 2002. Because this information had not been previously compiled prior to the Phase I study, a considerable effort was expended to locate and tabulate the data, verify its accuracy, and correct any errors.

OID records prior to 1987 were not compiled because they represent the irrigation system prior to extensive rehabilitation work that occurred in the mid 1980s. In 1977 only 18 percent of the OID's delivery system was piped and pressurized. During the rehabilitation the remainder of OID was converted to a pressurized system, the main canal was relined with reinforced concrete (except for a small portion passing through competent rock), and the Okanogan River pumping stations were either abandoned (Robinson Flats) or rebuilt (Shellrock). This resulted in a much more efficient delivery system. Therefore, irrigation diversion records prior the mid-1980s are not representative of current water use.

The 1987-2002 operation data provided by OID included:

- Conconully and Salmon Lake reservoir inflow, change in storage and outflows.
- Salmon Creek irrigation diversion and flow below the diversion.
- Duck Lake canal spill, Johnson Creek diversion, Duck Lake pumping quantities and Duck Lake end-of-month elevations.
- Shellrock Pumping quantities.
- Total system supply, delivery and efficiency calculations.

A few data gaps appear within this tabulation (as shown by blank entries), mostly in the Salmon Creek streamflow measurement below the OID diversion. Prior to 1996, OID did not have the capability of accurately measuring flows in Salmon Creek below the diversion dam. Because all flow in Salmon Creek was diverted to the canal, there was no flow in lower Salmon Creek except during periods of reservoir spill. In addition, no water was released from Conconully

Dam during the irrigation off-season, and OID often diverted Salmon Creek into the canal to recharge Duck Lake. Thus, little information is available for historical flows in lower Salmon Creek.

During the Phase I study, inspection of the data revealed inconsistencies between the measurements of outflow at Conconully Dam and the OID Salmon Creek diversion. During the irrigation season the two measurements should be similar (except when reservoir spill occurs), with the difference attributed to local inflow or channel loss between the dam and diversion. However, the historical data showed frequent unexplained differences in the two measurements, more than what local inflow or loss could contribute. The most likely source of error was assumed to be the measurement of outflow from Conconully Dam. Prior to 1997, flows were periodically measured at a 20-foot rectangular weir a few hundred feet downstream of Conconully Dam. That weir measured seepage from the dam as well as spill. However, in 1997 an aluminum ramp flume was installed in the dam outlet tunnel. That device does not measure Dam seepage and spill, and there is concern that it has not been accurately calibrated. In all years, estimation of spill rates is very approximate.

Additional confidence in recorded Conconully Dam outflow and OID diversion rates can be obtained only through a detailed review of daily flow measurements at the dam and an evaluation of the measurement weirs. This would require a large effort to process the data, and OID records are probably limited to only recent years.

Supply of Water to OID

OID obtains its water supply from Salmon Creek via the OID canal, Duck Lake, and the Okanogan River via the Shellrock pumping station. Duck Lake is supplied by the Johnson Creek diversion, OID canal spill and local runoff. Thus, OID water supply is defined as:

OID Water Supply = Salmon Creek diversion + Duck Lake + Okanogan River (Shellrock) pumping

Total annual water supply from these sources during the period 1987-2002 is summarized in C-4. From 1987 to 2002 Salmon Creek provided 84 percent of the total water supply of OID. However, the amount of water diverted varied by a wide range: from 10,665 acre-feet in 2002 to 20,834 acre-feet in 1998. Years with lower diversions usually have high pumping rates at Shellrock (e.g., 1992), but there are exceptions (e.g., 1993).

Table C-4. . Annual Quantities of OID Water Supply, 1987-2002 (acre-feet/year)

<i>Year</i>	<i>Salmon Creek</i>	<i>Duck Lake</i>	<i>Okanogan River</i>	<i>Total Water Supply</i>
1987	12,555	2,065	4,679	19,299
1988	11,441	2,141	4,499	18,081
1989	13,916	1,352	1,961	17,229
1990	15,942	1,083	0	17,025
1991	17,590	1,295	0	18,885
1992	10,882	916	4,526	16,324
1993	11,337	1,016	349	12,702
1994	14,032	1,161	981	16,174
1995	13,545	395	0	13,940
1996	18,302	309	0	18,611
1997	16,345	425	0	16,770
1998	20,834	697	0	21,531
1999	19,936	1,355	0	21,291
2000	18,262	995	0	19,257
2001	12,603	667	4,823	18,093
2002	10,655	1,738	5,910	18,303
Average	14,886	1,101	1,733	17,720
Percent	84.0%	6.2%	9.8%	100%
Minimum	10,655	309	0	12,702
Maximum	20,834	2,141	5,910	21,531

The amount of water diverted from Salmon Creek depends on two primary factors: the runoff volume in Salmon Creek and OID's overall water demand, which in turn primarily depends upon climatic conditions. The largest diversions occur during high runoff conditions combined with a hot summer, as occurred in 1998. Conversely, the lowest diversions occur when a lower runoff year combines with a cool summer, as occurred in 1992.

Duck Lake provided 6.2 percent and the Okanogan River provided 9.8 percent of the total water supply to OID from 1987 to 2002. Duck Lake pumping quantities do not vary significantly due to the water rights limitations placed on the Johnson Creek diversion and the limited ability of the lake to store water. Shellrock pumping, on the other hand, varies widely and supplements Salmon Creek and Duck Lake during years of below average runoff. At a current operating capacity of 25 cfs, Shellrock pumping station can potentially pump up to 8,700 acre-feet during the irrigation season. Since the maximum annual quantity of pumping during 1987-1998 was only 5,910 acre-feet, the total supply capability of Shellrock has been only partially used.

Total Irrigation Water Delivery

Total irrigation water delivery is the quantity of water delivered to the farmers via OID's distribution system. Due to the presence of Duck Lake, the quantity of irrigation water delivered is different from the quantity of irrigation water supplied. *Water supply* is the amount of water obtained from OID's water sources. *Water delivery* is the amount actually delivered to irrigation. *District efficiency* (the efficiency of the overall water delivery system) is defined by the ratio of water delivery to water supply. *On-farm efficiency* is defined by the ratio of crop requirements to water delivery.

Total irrigation delivery is defined as:

Total Irrigation Delivery = Salmon Creek diversion – canal spill to Duck Lake + Duck Lake pumping + Okanogan River (Shellrock) pumping.

Historical OID Water Delivery

Total annual quantities of annual irrigation water delivery during the period 1987-2002 are summarized in Table C-5. The average annual delivery of water to farmers from 1987 to 2002 was 15,518 acre-feet/year. This compares to the average OID water supply of 17,720 acre-feet (Table C-4). Thus, the overall efficiency of the water supply system is about 87.6 percent. The difference between water supply and water delivery, about 2,200 acre-feet/year, is equal to the amount of seepage loss from Duck Lake (see section below describing Duck lake water balance). A very small amount, about 60 acre-feet/year, also is lost through seepage from the main canal.

In many years the OID canal supplies over 90 percent of the water to farmers, with Duck Lake providing the remainder. Cutback of Salmon Creek diversions to as low as 60 percent of total irrigation demand occurs during dry years, with most of the remainder supplemented by Shellrock pumping. Duck Lake pumping is normally relatively constant due to its 10 cfs pump capacity. However, in the past few years the capacity has been limited to 6.6 cfs due to pump mechanical problems.

Table C-5. . Annual Quantities of OID Irrigation Delivery, 1987-2002 (acre-feet/year)

<i>Year</i>	<i>Salmon Creek</i>	<i>Less Canal Spill</i>	<i>Duck Lake Pumping</i>	<i>Shellrock Pumping</i>	<i>Total Irrigation Delivery</i>
1987	12,555	-1,977	2,065	4,679	17,322
1988	11,441	-2,372	2,141	4,499	15,709
1989	13,916	-1,886	1,352	1,961	15,343
1990	15,942	-2,883	1,083	0	14,142
1991	17,590	-2,536	1,295	0	16,349
1992	10,882	-1,883	916	4,526	14,441
1993	11,337	-1,801	1,016	349	10,901
1994	14,032	-2,410	1,161	981	13,764
1995	13,545	-2,253	395	0	11,687
1996	18,302	-2,235	309	0	16,376
1997	16,345	-2,336	425	0	14,434
1998	20,834	-2,908	697	0	18,623
1999	19,936	-2,919	1,355	0	18,372
2000	18,262	-1,797	995	0	17,460
2001	12,603	-1,578	667	4,823	16,515
2002	10,655	-1,447	1,738	5,910	16,856
Average	14,886	-2,201	1,101	1,733	15,518
Minimum	10,655	-1,447	309	0	10,901
Maximum	20,834	-2,919	2,141	5,910	18,623

Duck Lake is an important component of OID's water supply system because it allows for reuse of spill from the main canal, and it stores early spring runoff from Johnson Creek for use later in the irrigation season. If Duck Lake were not present, the water supply provided by Johnson Creek would be largely unavailable and canal spill could not be reused.

Correlation of Irrigation Delivery to Climate Conditions

Irrigation demand in OID is highly variable. As shown in Table C-5, recent annual irrigation deliveries ranged from a minimum of 10,901 acre-feet in 2002 to a maximum of 18,623 acre-feet in 1998. Many factors can contribute to the variability of irrigation demand; for the OID important variables include temperatures during the irrigation season, rainfall prior to and during the irrigation season, frost protection, cooling, and farmer's estimates on how much crop watering is needed during different climate conditions. Not all of these factors can be quantified.

For the purposes of the water supply model, irrigation demand was assumed to vary according to irrigation season temperatures. After looking at various ways to quantify the mean summer temperature using Omak data, it was found for the Phase I modeling efforts that weighting factors of 0.5, 1.0 and 1.0, respectively, for June, July and August temperatures produced the best correlation of irrigation delivery to temperature. These estimates have not been modified for the EIS. Rainfall was also evaluated, but by itself did not correlate well to irrigation demand. However, rainfall is usually inversely correlated to temperature (e.g., low rainfall is associated with warmer temperatures, and vice versa), and thus the irrigation demand-temperature correlation does incorporate rainfall indirectly.

Duck Lake Water Balance

A separate Duck Lake water balance model for the period 1987-1998 was conducted during the Phase I study and then elements of this model were incorporated within the Phase 1 water supply model. This was done to account for the seepage losses from the lake, the limitations on minimum and maximum elevations imposed by Ecology Order DE 85-20, and to include OID's groundwater sales. For EIS analysis, the water balance in Duck Lake is defined by the sum of inflows from spill in the OID canal and Johnson Creek, less seepage loss and Duck Lake pumping by OID.

Estimated average, minimum and maximum annual Duck Lake water budget quantities for the 1987-1998 period are summarized in Table C-6. Also shown are updated (through 2002) quantities for canal spill, Johnson Creek inflow and Duck Lake pumping. Estimated quantities of seepage have not been updated because the Duck Lake water balance model was not updated and re-run.

Based on the 1987-1998 data set, total loss of Duck Lake water to seepage ranged between 1,300 and 3,700 acre-feet per year, with an average of about 2,600 acre-feet/year. The water balance analysis showed that seepage loss from Duck Lake is highly dependent on elevation. For example, even though total water supply to Duck Lake increased steadily between 1987 and 1998 and pumping decreased by a significant amount, the average elevation of Duck Lake increased by only about eight feet.

During the 1995-1998 period, high inflows and very low pumping rates resulted in much greater seepage losses than in the late 1980's, when inflows were lower and pumping was higher. The Duck Lake water balance model determined that, to match the observed data, seepage losses are

on the order of 80 acre-feet/month at minimum lake elevations, but they increase to nearly 400 acre-feet/month at elevation 1,242 feet, which was common in 1998.

The elevation-storage curve is used to “buffer” the effects of monthly inflows and outflows, and determines the magnitude of fluctuation between maximum and minimum elevations in any given year. The water balance analysis estimated that Duck Lake and the connected shallow aquifer have a total usable storage of roughly 1,000 acre-feet in the lower 10 feet of the lake (between 1,227 and 1,237 feet), and up to roughly another 2,000 acre-feet in the upper 10 feet of the lake (up to 1,247 feet). These estimates are based on a simplified model and are very approximate.

Table C-6. Duck Lake Water Budget, 1987-1998 (acre-feet/year)

Year	<i>Inflow</i>		<i>Outflow</i>	
	Actual Canal Spill	Actual Johnson Creek	Estimated Seepage	Actual Pumping
Average	2290 (2,201)	1,483 (1,482)	2,626	1,071 (1,101)
Minimum	1,801 (1,447)	1,009 (861)	1,328	309 (309)
Maximum	2,908 (2,919)	2,156 (2,312)	3,675	2,141 (2,141)

Note: 1987-2002 quantities are in parentheses; the Duck Lake water balance model was not re-done, so updated seepage values are not available

Historical Operation of Duck Lake

Historical operations data for the period 1987-2002 were used to develop the parameters for the Duck Lake water budget contained in the water supply model. During 1987-2002 the magnitude of inflows to Duck Lake were substantially greater than outflows; the difference is the amount lost to seepage (and evaporation to a lesser degree). Total inflow averaged 3,684 acre-feet/year, whereas total pumping to OID at the Duck Lake pump station averaged only 1,101 acre-feet per year. Thus over the 16-year period, on average only 30 percent of the water entering Duck Lake has been used by OID for irrigation.

OID diverted large amounts of excess water to Duck Lake in the late 1990s during the high runoff conditions in Salmon Creek. In addition, Duck Lake pumping was cut back due to pump problems. Between 1995 and 1998, only 7% to 17% of the total inflow to Duck Lake was pumped by the OID. Because of the high volume of inflow and low pumping rates, the lake elevation rose above 1240 feet. As a consequence of the higher water elevations and high hydraulic heads that were established, seepage losses increased dramatically above an elevation of about 1232 feet. Thus, most of the added inflow during this time was lost to seepage and surcharging of the Duck Lake Groundwater Basin.

Water Balance Analysis

For Phase I study, the water balance in Duck Lake was governed by the following equation:

$$\text{Duck Lake storage} = \text{Canal inflow} + \text{Johnson Creek inflow} - \text{seepage loss} - \text{Duck Lake pumping}$$

Of the parameters in the above equation, all were known except the magnitude of seepage loss and the elevation-storage relationship for Duck Lake, which affected the calculation of monthly storage change. These parameters were estimated by creating a water balance model on a spreadsheet. An iterative process, involving varying the parameters in the loss rate equation and elevation-storage curve to match actual Duck Lake elevations, was used to calibrate the water balance. The equations for seepage loss and storage were assumed to follow an exponential curve function.

Table C-7 summarizes the resulting change in storage predicted by the model. The results reported in the Dames & Moore (1999) Phase 1 study showed a good match of modeled versus historical lake elevations for 1987-1998 data set using the assumed seepage loss rates and storage curve. However, the match was poorer in the early to mid-1990's, possibly due to poor data and/or unusual climate conditions.

Table C-7. . Duck Lake Water Budget, 1987-1998 (acre-feet/year)

Year	Inflow		Outflow		Estimated Change in Storage
	Actual Canal Spill	Actual Johnson Creek	Actual Pumping	Estimated Seepage Loss	
1987	1,977	1,372	2,065	1,328	-44
1988	2,372	1,322	2,141	1,448	+104
1989	1,886	1,281	1,352	1,560	+255
1990	2,883	1,396	1,083	2,660	+536
1991	2,536	1,009	1,295	2,471	-2221
1992	1,883	1,514	916	2,404	+77
1993	1,801	1,850	1,016	2,388	+247
1994	2,401	1,529	1,161	3,282	-504
1995	2,253	1,823	395	3,426	+255
1996	2,235	2,156	309	3,423	+658
1997	2,336	1,335	425	3,451	-204
1998	2,908	1,208	697	3,675	-256
Average	2,290	1,483	1,071	2,626	—
Minimum	1,801	1,009	309	1,328	—
Maximum	2,908	2,156	2,141	3,675	—

ANALYSIS OF EIS ALTERNATIVES

General Modeling Procedures

The four action alternatives were modeled following a rule that maintained the current firm yield for irrigation demand and allocated all additional water to instream flow. Each alternative water supply source was added to the model, and instream flow release rates for the middle and lower reaches of Salmon Creek were specified. If a new water supply source provided more than 100

percent of the instream flow need, the model showed that total water supply for irrigation and instream flow exceeded the demand, and a surplus of reservoir storage remained during the 1930s drought period. However, if demand exceeded supply, reservoir storage became exhausted in 1931 as indicated by negative storage in the model. To achieve a balance of supply and demand, the instream flow release was adjusted downward (using a factor between 0 percent and 100 percent) so that the total reservoir storage reached zero in 1931, in accordance with the definition of firm water supply described above.

If instream flow requirements are reduced during drought periods and/or irrigation curtailments are imposed, the operation of the water supply system will be less constrained by the need to maintain firm supply during the critical period, and greater volumes of water could be provided for instream flows during average and wet years. However, this water management strategy was not explored.

Modeling of the Alternatives

Appendix D provides a summary of essential model input and output data for the four action alternatives and the three flow scenarios (i.e., a total of 10 separate model runs). Appendix D contains printouts of model output for the four alternatives, documenting model parameters and simulation results. For simplicity and model control, certain operational conditions regarding Duck Lake were kept constant for all the model runs. These included:

- the Duck Lake Pumping capacity was kept constant at 10 cfs;
- the minimum Duck Lake elevation of 1226.75 ft had to be achieved before any pumping could occur;
- pumping from Duck Lake automatically occurred when the Duck Lake elevation exceeded 1232.0 ft; this is considerably less than the maximum permissible water elevation of 1247 ft, but by setting the maximum relatively low, less water was lost to seepage and greater operational efficiency was achieved;
- 500 acre-feet/year would be sold from Duck Lake artificially stored groundwater (i.e., the Duck Lake groundwater bank) to domestic, commercial and/or industrial users.

Most of the other pumping rules for Duck lake, Shellrock or the new 80 cfs pump varied to some extent depending on the water demands specified for each alternative and flow scenario. The only constant pumping rule was that there was not any cutback of pumping when the WAC instream flow requirements were not met. This assumption is supported by recognizing that even though WAC instream flow requirements are met only about 75% of the time, the relative proportion of pumped volumes to Okanogan river flow is usually very low. Further, except for the No Action Alternative, the Feeder Canal capacity was assumed to be a constant 90 cfs for all runs.

Modeling procedures and results for the water supply alternatives are described below. For each viable alternative, the water supply model was used to estimate how much water could be

obtained on a firm annual basis to supply each of the three instream-flow scenarios. The process used to determine the firm yield of each alternative was described above. Discussion of the modeling conducted for each alternative is provided below. Appendix D contains printouts of model output for the modeled alternatives, documenting model parameters and simulation results.

No Action Alternative

To evaluate the EIS alternatives, the water supply conditions for the No Action Alternative had to be defined. This condition defined the baseline, from which the alternatives were compared. Under the No Action Alternative, it was determined that OID's existing water supply sources were adequate to provide a firm supply of water to the irrigation system under all years of the 1904-2002 simulation period, assuming maximum pumping rates (25 cfs for 175 days or 7,856 ac-ft/year) of Shellrock are utilized throughout the irrigation season. These results were an improvement over the Phase I results, which predicted that under the same scenario (i.e., 25 cfs pump rate at Shellrock), a shortage would occur during the early 1930's drought period, equal to a capacity of about 24 cfs, with a peak volume deficit of 6,250 ac-ft in 1931. This deficit was assumed to begin affecting irrigation supply when the total reservoir storage fell below 3,000 ac-ft. Under the current model version several changes have been made, so the different results are likely attributed to a combination of:

- varying the monthly distribution of canal spill based on current OID practices rather than assuming a constant throughout the year; this yielded greater overall annual efficiency in the demand and distribution of simulated monthly water quantities;
- a minor reduction of the annual OID crop water requirements to reflect the predicted needs over the next 5 years rather than the crop water requirements that have occurred over the last 16 years;
- following the Duck Lake pumping rules strategy as outlined above;
- increasing the critical storage level to 9,500 ac-ft (rather than 3,000 ac-ft) at which maximum pumping from Shellrock occurred; and
- reconfiguring the maximum monthly pumping load factors for Duck Lake and Shellrock to allow maximum pumping at any time.

These adjustments were made in an attempt to maximize the current OID practices and would reflect potential management strategies designed to conserve water for a critical drought period. The exercise also demonstrates that although the current water system model does not exactly reflect OID operations, further refinements and improvements to the model are possible.

For the No Action Alternative, the water system model predicts a firm yield of 448 ac-ft of flow over the Salmon Creek weir and 354 ac-ft at the mouth of Salmon Creek (Appendix D-1). Average annual flow over the weir is estimated at 10,501 ac-ft/yr. The predicted average combined storage for the 99-year period was 19,178 ac-ft/yr, with a minimum annual storage

volume (occurring in 1931) 1,748 ac-ft. Predicted average annual total OID demand from the water supply system is 15,745 ac-ft/yr, with an overall district efficiency of 70%. Under this alternative, Salmon Creek supplies about 78% (12,229 ac-ft/yr), Shellrock 15% (2,414 ac-ft/yr) and Duck Lake 7% (1,101 ac-ft/yr) of the total supply. Predicted average annual efficiencies for on-farm and delivery are 77% and 91% (compared to 76% and 86% for the Phase I study), respectively.

Action Alternative 1 Okanogan River Pump Water Exchange

This alternative involves constructing a new 80 cfs pump station on the Okanogan River to supply water to the OID irrigation canal. This would allow OID to reduce Salmon Creek diversions for irrigation water, leaving more water for instream flow needs. The only change to model assumptions from the No Action Alternative involved the abandonment of all pump capacity from Shellrock, and the installation of a greater capacity pump farther downstream. All other pumping rules for Duck Lake were the same, and it was assumed (by the model structure) that water would be pumped from the new 80 cfs pump station first before taking water from the Salmon Creek diversion combined storage.

The model assumed that pumping would provide water directly to the OID main canal (just downstream of lateral #1). Pumping would occur at maximum pump capacity or the irrigation demand, whichever was lower, except during periods of reservoir spill. During spill, pumping would be cut back and Salmon Creek diversions would increase (subject to instream flow requirements). During low-runoff years, the model supplements the irrigation supply with Duck Lake pumping. Irrigation demand not supplied by pumping would be obtained from Salmon Creek.

The total amounts of water supplied for the three flow scenarios under the new 80 cfs Okanogan River pumping alternative are summarized in Appendix D-1. The water system model predicts firm yields ranging from 4,027 to 5,081 ac-ft for the three flow scenarios, and 5,100 to 6,435 ac-ft of flow over the Salmon Creek. Average annual flow over the weir is much higher than the No Action Alternative and ranged from 16,990 to 17,342 ac-ft/yr. This is a reflection of maintaining higher overall storage volumes in Conconully and Salmon Lake reservoirs. For the three scenarios under this alternative the average combined storage for the 99-year period ranged from 21,640 to 22,840 ac-ft/yr (compared to 19,178 ac-ft for the No Action), with minimum annual storage volumes ranging from 2,223 to 13,568 ac-ft (compared to 1,748 ac-ft for the No Action).

Predicted average annual total OID demand from the water supply system is 16,155 ac-ft/yr (slightly higher – about 2.6% - than the No Action Alternative due to lower efficiencies), with an overall district efficiency of 68%. Under this alternative, Salmon Creek supplies about 33-35%, the new pump station 56-59% and Duck Lake 8-9% of the total supply. Predicted average annual efficiencies for on-farm and delivery are 77% and 89%, respectively.

Action Alternative 2 Upgrade Shellrock Pumping Plant

This alternative involves upgrading Shellrock to take the full 35 cfs allowed under OID's water rights. The additional 10 cfs of pump capacity would allow OID at certain times to reduce the demand on Salmon Creek for irrigation water, leaving more water for instream flow needs.

Only a few of other modeling rules that were applied for the No Action Alternative were changed. It was assumed that Duck Lake could pump at a maximum capacity at any time during the irrigation season. All other pumping rules for Duck Lake were the same, and it was assumed (by the model structure) that water would be pumped from Shellrock first before taking water from the Salmon Creek diversion combined storage. Further, maximum pumpage from Shellrock was invoked when combined storage went below 15,000 ac-ft (as opposed to 9,500 ac-ft for the No Action). Further, pumping would occur at maximum pump capacity or the irrigation demand, whichever was lower, even during periods of reservoir spill. This allowed more water to be saved in reservoir storage to cover the critical drought period. During low-runoff years, the model supplements the irrigation supply with Duck Lake pumping. Ultimately, irrigation demand not supplied by pumping would be obtained from Salmon Creek.

The total amounts of water supplied for the three flow scenarios under the Shellrock Upgrade Alternative are summarized in Appendix D-1. The model predicts no shortages for the two Steelhead flow scenarios, but that under the flow scenario for Steelhead and Chinook, a small shortage would occur when conditions are similar to the early 1930's drought period. The shortage is modeled to persist for four years, with a peak critical storage deficit of 1,678 acre-feet per year in the second year of the drought sequence. This deficit occurred even though pumping from Duck Lake and Shellrock was maximized when critical storage volumes in Conconully and Salmon Lake reservoirs fell below 15,000 ac-ft. Thus, the model suggests that the significantly greater instream flow demands for maintaining Chinook species will impact the OID water system when drought conditions are similar to those experienced in the late 1920's and early 1930's.

After adjusting for the critical storage deficit, the water system model predicts firm yields ranging from 4,027 to 5,067 ac-ft for the three flow scenarios, and 5,100 to 6,417 ac-ft of flow over the Salmon Creek weir. Average annual flow over the weir is much higher than the No Action Alternative and ranges from 15,636 to 16,706 ac-ft/yr. This is a reflection of the instream flow needs and maintaining higher overall storage volumes in Conconully and Salmon Lake reservoirs. For the three scenarios under this alternative the average combined storage for the 99-year period ranged from 21,153 to 21,594 ac-ft/yr (compared to 19,178 ac-ft for the No Action), with minimum annual storage volumes ranging from 180 to 346 ac-ft (compared to 1,748 ac-ft for the No Action).

Predicted average annual total OID demand from the water supply system ranged from 14,425-15,225 ac-ft/yr (about 3.4-8.4% lower than the No Action Alternative due to higher efficiencies), with an overall district efficiency of 72-76%. Under this alternative, Salmon Creek supplies about 41-46%, Shellrock 47-52% and Duck Lake 7% of the total supply. Predicted average annual efficiencies for on-farm and delivery are 78-82% and 93%, respectively.

Action Alternative 3 Okanogan Irrigation District Water Right Purchase

This alternative involves the purchase of 5,100 ac-ft/yr of water rights from the OID. The effect of this alternative is to reduce OID demands on Salmon Creek water, and make it available for the specified instream flow demands for Steelhead or Steelhead and Chinook.

To achieve the intent of this alternative, OID irrigation demands had to be reduced by some amount to reflect the loss of 5,100 ac-ft/yr. This essentially meant retiring acreage and reducing the overall OID on-farm crop water requirements by the four following steps:

- 1) **Determine crop water demand per acre.** A revised total crop water demand for the OID 5,032 acres was estimated based on projected crop type per acre for the next five years (the average demand worked out to be 2.19 ac-ft/acre - at an average OID system efficiency 67%, the total demand works out to be 3.27 ac-ft/acre).
- 2) **Determine total crop water demands.** Based on these numbers, the average, minimum and maximum crop water demands were calculated to be 11,025, 10701, and 11,350 ac-ft, respectively (which is a little less than what OID currently claims).
- 3) **Determine total on-farm water demands.** Assuming minimum and maximum on-farm efficiencies of 66% and 85%, respectively, yields minimum and maximum total on-farm water demands (i.e., what is delivered to farms - canal spill in Duck Lake is additional) of 12,590 and 17,196 ac-ft, respectively (these values yield a slightly smaller range than what OID has done historically since 1987).
- 4) **Reduce on-farm water demands by reducing acreage.** The objective was to retire enough acreage to achieve on average (over the 99-year period) approximately 5,100 ac-ft/yr less water demand from system. The total acreage was reduced by iteratively multiplying the existing acreage by a fraction (i.e., 0.68 or 3422 acres) within the model to achieve a long-term average of approximately 5,100 ac-ft. At an average system efficiency of approximately 67% this means that the total reduction of 1,610 acres (or $5,032 - 3,422$ acres) on average would be about $3,422/0.67 = 5,107$ ac-ft.

The above scenario yielded minimum and maximum crop water demands of 7,277 and 7,718 ac-ft/yr, respectively, which are 3,424 and 3,632 ac-ft/yr, respectively, lower than the No Action Alternative crop water demands. At 66% and 85% efficiencies the minimum and maximum on-farm water demands worked out to be 8,561 and 11,694 ac-ft/yr. Subtracting from the minimum and maximums in (3) yielded differences of 4029 and 5502 AF, respectively.

All other modeling rules applied for the No Action Alternative were assumed except for the allowing Duck Lake to pump at maximum capacity at any time during the irrigation season. All other pumping rules for Duck Lake were the same, and it was assumed (by the model structure) that water would be pumped from Shellrock first before taking water from the Salmon Creek diversion combined storage. Further, maximum pumpage from Shellrock was invoked when combined storage went below 15,000 ac-ft (as opposed to 9,500 ac-ft for the No Action). Further, pumping would occur at maximum pump capacity or the irrigation demand, which ever

was lower, even during periods of reservoir spill. This allowed more water to be saved in reservoir storage to cover the critical drought period. During low-runoff years, the model supplements the irrigation supply with Duck Lake pumping. Ultimately, irrigation demand not supplied by pumping would be obtained from Salmon Creek.

The total amounts of water supplied for the three flow scenarios under the Water Rights Purchase Alternative are summarized in Appendix D-1. The model predicts no shortages for the two Steelhead flow scenarios, but that under the flow scenario for Steelhead and Chinook, a small shortage would occur when conditions are similar to the early 1930's drought period. The shortage is modeled to persist for two years, with a peak critical storage deficit of 674 acre-feet per year in the first year of the drought sequence. This deficit occurred even though pumping from Duck Lake and Shellrock was maximized when critical storage volumes in Conconully and Salmon Lake reservoirs fell below 15,000 ac-ft. Thus, the model suggests that the significantly greater instream flow demands for maintaining Chinook species will impact the OID water system when drought conditions are similar to those experienced in the late 1920's and early 1930's.

After adjusting for the critical storage deficit, the water system model predicts firm yields ranging from 4,027 to 5,973 ac-ft for the three flow scenarios, and 5,100 to 7,565 ac-ft of flow over the Salmon Creek weir. Average annual flow over the weir is much higher than the No Action Alternative and ranged from 17,202 to 18,606 ac-ft/yr. This is a reflection of the higher instream flow demands and maintaining higher overall storage volumes in Conconully and Salmon Lake reservoirs. For the three scenarios under this alternative the average combined storage for the 99-year period ranged from 21,226 to 22,004 ac-ft/yr (compared to 19,178 ac-ft for the No Action), with minimum annual storage volumes ranging from 426 to 2,911 ac-ft (compared to 1,748 ac-ft for the No Action).

Predicted average annual total OID demand from the water supply system ranged from 9,972 to 10,679 ac-ft/yr (or about 63-68% of the No Action Alternative due to primarily the retired acreage), with an overall district efficiency of 70-75%. Under this alternative, Salmon Creek supplies about 41-51%, Shellrock 54-51% and Duck Lake 5-8% of the total supply. Predicted average annual efficiencies for on-farm and delivery are 75-82% and 92-93%, respectively.

REFERENCES

Dames & Moore, 1999. Joint Study of Salmon Creek. Prepared for Colville Confederated Tribes and the Okanogan Irrigation District, September 30, 1999.

Doty, J. March 9, 1999. Computer Records of Conconully Dam and Salmon Lake Dam Data, 1946-1999. James Doty, U.S. Bureau of Reclamation, Pacific Northwest Region, Boise, ID.

Bureau of Reclamation, 1968. Chief Joseph Dam Project, Washington; Okanogan-Similkameen Division; Okanogan Unit; Appendix B – Water. U.S. Bureau of Reclamation, Upper Columbia Development Office, Spokane, WA.

Bureau of Reclamation, 1989. Standard Operating Procedures, Conconully Dams. Okanogan Project, Washington. U.S. Bureau of Reclamation, Pacific Northwest Region, Boise, ID. June 1989.

Bureau of Reclamation, 1989. Standard Operating Procedures, Salmon Lake Dam. Okanogan Project, Washington. U.S. Bureau of Reclamation, Pacific Northwest Region, Boise, ID. June 1989.

OID, 1998. Conservation and Management Plan. Okanogan Irrigation District, Okanogan, WA. October 22, 1998 draft.

Frazier, P., June 7, 1999. Historical Irrigation Operation Data, 1987-1998. Personal communication (fax) from Paul Frazier, Okanogan Irrigation District, to consultant team members.

Attachment Table C-1. Model Components and Operation Rules
Not Modified from 1999 Phase 1 Report (Dames and Moore)

Model Component	Variables	Definition	Operation Rules	Modifications for Irrigation or Instream Flow Yield
Inflow time series	Unregulated Salmon Creek	Total monthly runoff volumes for entire Salmon Creek watershed above Conconully Dam	Used to calculate watershed runoff into storage reservoirs	None
	Distribution factors for Salmon Creek tributaries	Percent of total watershed runoff in each tributary	46% for North Fork, 35% for West Fork, 16% for South Fork, and 3% for Salmon Lake tributary	None
	Middle reach gain or loss	Flow volumes entering Salmon Creek middle reach, either as gain (during wet years) or loss (during dry years)	Gain or loss is based on Omak March-July precipitation. Volumes are included in the irrigation demand calculation	None
	Omak mean summer temperature	Historical average yearly summer temperatures, based on following weighting: $(0.5 \cdot \text{June} + 1.0 \cdot \text{July} + 1.0 \cdot \text{Aug}) / 2.5$	Used to determine OID irrigation demand and (optionally) pumping rates in Duck Lake and Shellrock	None
	Omak precipitation	Historical precipitation at Omak, for water year and March-July.	Used to determine middle reach gain or loss (March-July) and Johnson Creek diversion (water year).	None
	Historical Okanogan River flows	Historical monthly flow in Okanogan River, adjusted to reflect unregulated Salmon Creek discharge to the river	Used to evaluate impacts of pumping on river flows	None
Irrigation Demand	Maximum Irrigation Requirement	Required water supply to farms during warm years (75 deg. or higher)	Irrigation demand is based on crop irrigation requirement and pro-rated between max and min based on average Omak temperature.	Modify based on new crops, acres of irrigation, or OID Water Bank.
	Minimum Irrigation Requirement	Required water supply to farms during cool years (67 deg. or higher)		
	On farm efficiency	Crop irrigation requirement divided by water supplied to farms	Determined by recent irrigation practices. Currently ranges between 66% for warm years to 98% for cool years.	Change efficiency based on conservation or revised operation practices.
Duck Lake Groundwater Demand	Annual groundwater sale	Total annual quantity of groundwater pumped from Duck Lake system	Firm pumping rates during all years, unaffected by Duck Lake storage level. Annual distribution based on specified monthly percents. Assumed to equal 500 ac-ft/yr.	Increase to 1000 ac-ft/yr. See report for discussion of whether 1000 ac-ft/yr can be attained.

Attachment Table C-1. Model Components and Operation Rules
Not Modified from 1999 Phase 1 Report (Dames and Moore)

Model Component	Variables	Definition	Operation Rules	Modifications for Irrigation or Instream Flow Yield
Delivery System	Conveyance efficiency	Percent of canal flow loss to seepage	Set to constant 0.6%	Assume 0% under pressurized conveyance system
	Operation efficiency	Percent of canal flow spilled to Duck Lake	Set to constant 13.4%	Assume 0% under pressurized irrigation operations
Duck Lake Water Balance	Johnson Creek inflow	Monthly inflow from Johnson Creek diversion, based on historical rates correlated to annual Omak precipitation. Total annual quantity is distributed into monthly amounts based on specified percentages.	Water balance includes Johnson Creek inflow, seepage loss, groundwater pumping, and canal spill. Total rates and quantities for each are based on analysis of 1986-1998 Duck Lake inflow, outflow, and elevation.	Modify pumping rates and rules to improve Duck Lake yield or peak pump capacity (see below)
	Seepage Loss	Loss of Duck Lake storage to seepage and evaporation.		
Duck Lake Pumping	Pump capacity	Capacity of pump in cfs	Monthly pumping volumes are limited by installed capacity	None (fixed at 10 cfs by water right).
	Maximum Pump Rate	Pumping rate during warm years (75 deg. or higher)	Normal pump rates when Duck Lake is between minimum and maximum levels, and reservoir storage is above critical. Monthly pumping volumes are based on monthly pump load factors to match monthly irrigation demand.	Modify rates to increase yield, subject to other operational rules
	Minimum Pump Rate	Pumping rate during cool years (67 deg. or higher)		
	Maximum Duck Lake elevation	Maximum operating level of Duck Lake	Increase pumping rate to peak capacity to keep Duck Lake level below maximum	Reduce elevation to minimize seepage loss, at the expense of lower peak firm capacity.
	Minimum Duck Lake elevation	Minimum operating level of Duck Lake	Decrease pumping if elevation falls below minimum	None
	Critical reservoir storage for reserve Duck Lake pumping	Storage in combined system (Conconully, Salmon Lake, etc.) to trigger additional pumping	Pumping rate is increased to peak capacity to maximize yield, subject to minimum elevation rule.	Set critical storage higher to trigger more frequent maximum pumping

Attachment Table C-1. Model Components and Operation Rules
Not Modified from 1999 Phase 1 Report (Dames and Moore)

Model Component	Variables	Definition	Operation Rules	Modifications for Irrigation or Instream Flow Yield
Shellrock Pumping	Pump capacity	Capacity of pump in cfs	Monthly pumping volumes are limited by installed capacity	Increase pump capacity
	Maximum Pump Rate	Pumping rate during warm years (75 deg. or higher)	Normal pump rates when reservoir storage level is above critical. Monthly pumping volumes are based on monthly pump load factors to match monthly irrigation demand. Pumping is reduced when reservoir spill occurs.	Modify rates to increase yield, subject to other operational rules
	Minimum Pump Rate	Pumping rate during cool years (67 deg. or higher)		
	No Shellrock Pumping during remainder of year if spill occurs	Flag for indicating pump operation during years of spill	If "Yes", pumping stops for remainder of year if spill occurs. If "No", pumping resumes in first month of no spill.	Set to "No" to maximize pumping during years when spill occurs.
	Critical reservoir storage for reserve Shellrock pumping	Storage in combined system (Conconully, Salmon Lake, etc.) to trigger additional pumping	Pumping rate is increased to peak capacity to maximize pumping yield.	Set critical storage higher to trigger more frequent maximum pumping
Emergency Supplemental Pumping	Pump capacity that can be installed under emergency authorization during extended drought period	Capacity of pump in cfs.	Pumping occurs when total storage falls below critical level. Capacity and critical storage level are based on amount needed to achieve firm water supply under current operation and irrigation demand.	None. No emergency pumping is assumed for OID operations.
	Critical reservoir storage for supplemental pumping	Storage in combined system (Conconully, Salmon Lake, etc.) to trigger additional pumping		
New Pumping Facilities	New Okanogan River Pumping (upstream or downstream of Salmon Creek)	Capacity of new pumping station, pumping water from Okanogan River to head of OID canal	Pumped water is supplied to canal at monthly quantities up to the maximum irrigation demand in the canal. Pumping occurs only during irrigation season. Location of pump station determines affects the flow in the Okanogan River.	Add new pumping to supplement or replace Shellrock, allowing reduced irrigation withdrawal from Salmon Creek.

Attachment Table C-1. Model Components and Operation Rules
Not Modified from 1999 Phase 1 Report (Dames and Moore)

Model Component	Variables	Definition	Operation Rules	Modifications for Irrigation or Instream Flow Yield
New Pumping Facilities (cont'd)	Pumping from Salmon Creek to Brown Lake	Total capacity of pump diversion from Salmon Creek to new storage reservoir at Brown Lake	Monthly pumping rates are specified for all months of the year. Storage is released to OID canal based on specified monthly outflow rates. If total capacity is greater than monthly pumping rates, additional spill will be diverted up to installed capacity.	Add new storage for new dam, providing additional system storage capacity
	Pumping from Salmon Lake to Aquifer Storage and Recovery	Total capacity of pump diversion from Salmon Lake to new aquifer storage reservoir		
Other Water Supply	Watercress Springs water supply	Monthly flow volumes supplied to Salmon Creek from Watercress Springs	Flows are added to Salmon Creek in constant monthly amounts	New water supply sources to provide/supplement instream flows
	Other supply	Monthly flow volumes supplied from other sources to upper or lower segment of Salmon Creek		
Reservoir System	Conconully storage	Total active reservoir storage volume	Natural runoff of Salmon Creek is stored by reservoir. Runoff in excess of capacity is spilled.	None
	Salmon Lake storage	Total active reservoir storage volume		Increase storage of existing reservoir with raised dam, providing additional system storage capacity
	New West Fork storage	Total active reservoir storage volume		Add new storage for new dam, providing additional system storage capacity
	New Brown Lake or Aquifer storage	Total active reservoir storage volume (for either facility; it is assumed that both facilities will not be evaluated together)	Offline reservoir is supplied by new pump facility	Add new storage for new dam, providing additional system storage capacity
	Feeder canal capacity	Capacity of feeder canal from North Fork to Salmon Lake reservoir	Diversion from North Fork is limited to feeder canal capacity	Increase canal capacity to provide additional water to Salmon Lake
	Storage release factors	Percent of total system demand released from each reservoir	Monthly storage release from the reservoirs is proportioned based on these factors.	Modify to optimize storage release, such that all reservoirs are equally depleted to zero storage during critical year.

Attachment Table C-1. Model Components and Operation Rules
Not Modified from 1999 Phase 1 Report (Dames and Moore)

Model Component	Variables	Definition	Operation Rules	Modifications for Irrigation or Instream Flow Yield
Instream Flow Demand	Salmon Creek lower reach, upper segment loss	Loss of stream flow to channel seepage	Loss is expressed as constant percent of total stream flow.	None
	Salmon Creek lower reach, lower segment loss			
	Instream flow demand	Monthly flow rates to be released from reservoir for the lower reach of Salmon Creek	Instream flow scenario is specified. Water supply demand is placed on reservoir storage in addition to irrigation demand. If irrigation demand or spill provided the instream flow, this release is not counted as an instream flow.	Add new instream demand for lower Salmon Creek
	Percent of instream flow release met	Factor to modify magnitude of instream flow release	Used to determine how much of the total instream flow demand is met by a given alternative.	Total instream flow demand is met if 100% is specified.
	Daily flow release	Daily flow schedule for instream flow release	Used to specify variable instream flows using daily flow rates over a two-week period. Daily flows are converted to monthly flow rates.	Variable instream flow rates.

**Attachment Table C-2. Prioritization of Water Supply Sources
Not Modified from 1999 Phase 1 Report (Dames and Moore)**

Order of Water Supply Calculations	Rules
1. Total reservoir demand	<ul style="list-style-type: none"> • Based on mean Omak summer temperature and irrigation conveyance and operation efficiencies, total irrigation demand is calculated • Instream flow rates are added to reservoir demand • Initial assumptions on pumping rates for Duck Lake and Shellrock are determined (based on percent of total installed capacity) and subtracted from irrigation demand to be supplied from reservoir. • Reserve pumping capacity from Shellrock (during low reservoir storage), supplemental emergency pumping (during critically low reservoir storage), and new Okanogan River pump facilities are subtracted from reservoir demand • Total reservoir demand is adjusted for middle reach inflow or outflow, and for increased or decreased canal losses that are caused by the modified pumping rates describe above.
2. Duck Lake Pumping	<ul style="list-style-type: none"> • Allowable Duck Lake pumping rate (subject to maximum and minimum lake levels) is determined through a water balance of that system. • Optionally, different pumping rates can be specified for warm and cool years, and maximum capacity can be done during critical drought periods when total system storage (Conconully + Salmon Lake) falls below a specified minimum storage. • Additional pumping at Duck Lake reduces the diversion from Salmon Creek, resulting in lower canal loss; this adjustment is made in model.
3. Shellrock Pumping	<ul style="list-style-type: none"> • Optionally different pumping rates can be specified for warm and cool years, and pumping at maximum capacity (up to the monthly irrigation demand) can be done during critical drought periods as described above. • Shellrock pumping is minimized when the reservoir spills, either for the entire year or just for the months of spill. Less pumping means more diversion from Salmon Creek, resulting in additional canal loss.
4. Required reservoir release	<ul style="list-style-type: none"> • Conconully and Salmon Lake reservoirs are operated to supply the irrigation demand not supplied by Duck Lake, Shellrock, or the new pump facilities. • New alternative reservoirs (i.e., raising Salmon Lake, new West Fork, Brown Lake, and ASR) are operated similarly.
5. Salmon Creek and Okanogan River flows	<ul style="list-style-type: none"> • Flow in lower Salmon Creek is calculated based on the specified instream flow releases, reservoir spill, and channel loss. • Flow in Okanogan River is calculated based on historical flow rates above Shellrock, total amount of Okanogan River pumping, and discharge of Salmon Creek.

**Attachment Table C-3. Model Supply Model Parameters
Not Modified from 1999 Phase 1 Report (Dames and Moore)**

Column Number	Category	Parameter	Description
1	General input	Year	Calendar year
2		Month	Jan-Dec label
3		Average Omak summer temperature	Used to estimate irrigation demand and (optionally) pumping rates for Shellrock and Duck Lake
4		Water year precipitation	Used to estimate Johnson Creek diversion amount
5	Watershed runoff	Total unregulated watershed runoff.	Total natural flow entering Conconully and Salmon Lake reservoirs
6		North Fork.	Percent of total watershed runoff partitioned to North Fork. Fixed at 46%.
7		West Fork	Percent of total watershed runoff partitioned to West Fork. Fixed at 35%.
8		South Fork	Percent of total watershed runoff partitioned to South Fork. Fixed at 16%.
9		Salmon Lake Fork	Percent of total watershed runoff partitioned to Salmon Lake tributary. Fixed at 3%.
10	Total Reservoir Demand	Assumed initial Shellrock pumping	Monthly pumping rate based on model input. Will be subsequently modified if spill is available to reduce pumping or critical storage requires additional pumping.
11		Max Shellrock flow under WAC minimum instream flow	Based on input water right, the maximum allowable monthly pumping at Shellrock when flow in Okanogan River falls below WAC minimum instream flow rate.
12		Irrigation demand - demand at laterals	Initial estimate of diverted Salmon Creek water needed for delivery to farmers, based on model input.
13		Irrigation demand - additional canal loss	Additional diverted water to make up for canal seepage loss and end spill
14		Instream flow release - middle reach	Required instream flow based on model input. Checks to determine if irrigation demand already provides flow in middle reach.
15		Instream flow release - lower reach	Required instream flow based on model input.
16		Brown Lake or ASR - diversion from Salmon Creek	Based on input data, amount of reservoir release needed for pumping from Salmon Creek to Brown Lake or ASR.
17		Brown Lake or ASR - release during critical period	Based on input data, amount of water released from Brown Lake or ASR during when system storage falls below level specified in input.
18		Less middle reach flow	Middle reach flow, input as a time series, is factored into the irrigation demand (i.e., middle reach inflow is available for diversion)
19		Pumping adjustments - Shellrock critical period	Additional Shellrock pumping occurs if system storage falls below level specified in input.
20		Pumping adjustments - Shellrock limit during WAC	Pumping is reduced to amount in column (11) if Okanogan River flow falls below WAC minimum
21		Pumping adjustments - additional pumping for system deficit	If specified, additional pumping to meet critical period demand is provided from separate source (e.g., emergency pump installation or equivalent reduction in irrigation demand) if system storage falls below level specified in input.
22		Pumping adjustments - adjustment of canal loss	Based on the amount of reduced or increased Shellrock pumping, the canal loss in column (13) is adjusted.

**Attachment Table C-3. Model Supply Model Parameters
Not Modified from 1999 Phase 1 Report (Dames and Moore)**

Column Number	Category	Parameter	Description
23	Total Reservoir Demand (cont'd)	New Okanogan River pumping - less new pumping	Total reservoir demand is reduced by new Okanogan River pumping. Canal losses remain the same with pumping and thus do not need to be adjusted.
24		New Okanogan River pumping - adjust for pump limit during WAC	Pumping is reduced to amount specified in input data if Okanogan River flow falls below WAC minimum
25		Total demand	Total reservoir demand from Salmon Lake and Conconully reservoir storage
26	Salmon Lake Reservoir	Salmon Creek demand	Total demand in column (25) multiplied by input factor "percent of reservoir release from Salmon Lake"
27		Total reservoir release	Equal to column (26)
28		Reservoir inflow	Inflow to Salmon Lake reservoir, equal to feeder canal capacity of North Fork plus Salmon Lake Fork.
29		Storage before diversion	Previous month's storage (33) plus current month inflow (28)
30		Storage after diversion	Storage before diversion (29) minus Salmon Creek demand (26)
31		Revised spill	Amount of storage after diversion that is greater than reservoir capacity
32		Total outflow	Reservoir release (27) plus spill (31)
33		End storage	End of month storage after inflow, release, and spill
34	Conconully Reservoir	Required reservoir release	Total demand in column (26) multiplied by input factor "percent of reservoir release from Conconully"
35		Storage adjustment from previous month	Storage from column (101) that was derived from spill and pumping refinements later in the model.
36		Reservoir inflow	Inflow to Conconully reservoir, equal to Salmon Lake outflow plus West Fork, South Fork and amount left in North Fork after feeder canal diversion
37		Storage before diversion	Previous month's storage (41) plus current month inflow (34) plus storage adjustment (35)
38		Storage after diversion	Storage before diversion (37) minus required reservoir release (34)
39		Spill	Amount of storage after diversion that is greater than reservoir capacity
40		Total outflow	Reservoir release (34) plus spill (39)
41		End storage	End of month storage after inflow, release, and spill
42	Combined system storage	Combined system storage	Total storage in Conconully and Salmon Lake reservoirs at end of month
43	Reduce pumping during spill; add spill to Salmon Creek diversion	Shellrock pumping with adjustments: Shellrock pump	Initial estimate of Shellrock pump, equal to column (10)
44		Shellrock pumping with adjustments: Shellrock critical	Shellrock critical period pumping, equal to column (19)
45		Shellrock pumping with adjustments: Additional spill to Shellrock	If spill is available, Shellrock pumping is reduced and water is sent to canal
46		Shellrock pumping with adjustments: Canal losses	Adjustment to canal loss because Shellrock pumping has no conveyance or end spill loss
47		Shellrock pumping with adjustments: Revised pump	Revised estimate of Shellrock pumping
48		Revised spill	Revised Conconully spill after reducing Shellrock pumping and sending more water to OID canal

**Attachment Table C-3. Model Supply Model Parameters
Not Modified from 1999 Phase 1 Report (Dames and Moore)**

Column Number	Category	Parameter	Description
49	Reduce pumping during spill; add spill to Salmon Creek diversion (cont'd)	New Okanogan pumping: Okanogan Pumping	New Okanogan pumping, from column (23)
50		New Okanogan pumping: additional spill to canal	If spill is available, Okanogan River pumping is reduced and water is sent to canal
51		New Okanogan pumping: revised pumping	Revised estimate of Okanogan River pumping
52		Revised spill	Revised Conconully spill after reducing Okanogan River pumping and sending more water to OID canal
53		Additional pumping to Brown Lake: Brown pump	Brown Lake pumping, from column (16)
54		Additional pumping to Brown Lake: additional spill to Brown Lake	If pump capacity is available during spill, pump up to maximum rate to Brown Lake or ASR
55		Additional pumping to Brown Lake: revised pumping	Revised estimate of pumping to Brown Lake, equal to column (16) plus column (54)
56		Revised spill	Revised Conconully spill after additional Brown Lake pumping
57	Do not count instream flow release during spill	Unadjusted instream flow - middle reach	Instream flow release for middle reach, from column (14)
58		Unadjusted instream flow - lower reach	Instream flow release for lower reach, from column (15)
59		Revised instream flow - middle reach	If spill occurs during month, reduce instream flow release quantity because spill would have occurred anyway
60		Revised instream flow - middle reach	If spill occurs during month, reduce instream flow release quantity because spill would have occurred anyway
61		Revised spill	Revised Conconully spill after adding back instream flow that actually is spill.
62	New Brown Lake Reservoir/ Aquifer Storage and Release	Required reservoir release	Release from Brown Lake, as specified in input data. Same as column (17).
63		Reservoir inflow	Amount of pumping to Brown Lake or ASR, equal to column (55)
64		Storage before diversion	Previous month's storage (68) plus current month inflow (63)
65		Storage after diversion	Storage before diversion (64) minus required reservoir release (62)
66		Spill	Amount of storage after diversion that is greater than reservoir capacity
67		Total outflow	Reservoir release (62) plus spill (65)
68		End storage	End of month storage after inflow, release, and spill
69	OID Canal	Salmon Creek diversion	Total amount of water diverted from Salmon Creek, based on reservoir release and pumping adjustments: (12) + (13) + (19-24) + (45) + (50) + (67)
70		New Okanogan River pumping	Revised estimate of pumping from column (51)
71		Conveyance loss	Canal conveyance loss based on percentage entered in input data times canal flow
72		Canal spill	Canal spill based on percentage entered in input data times canal flow
73		Net canal supply	Total canal supply delivered to laterals

Attachment Table C-3. Model Supply Model Parameters
Not Modified from 1999 Phase 1 Report (Dames and Moore)

Column Number	Category	Parameter	Description
74	Duck Lake Water Balance	Johnson Creek diversion	Johnson Creek diversion, based on regression of annual diversion amount (input time series data) and water year Omak precipitation (column 4)
75		Canal spill	Canal spill from column (72)
76		Storage adjustment from previous month	Storage from column (100) that was derived from spill and pumping refinements later in the model.
77		Total inflow	Total inflow to Duck Lake, columns (74) + (75) + (76)
78		Storage before diversion	Previous month's storage (87) plus current month inflow (77)
79		Duck Lake pumping adjustments: assumed initial	Initial assumed Duck Lake pumping rate, from input data
80		Duck Lake pumping adjustments: additional critical	If specified, additional Duck Lake pumping if lake storage falls below a specified level
81		Duck Lake pumping adjustments: Adjust for storage available	If lake storage falls below minimum specified in input, reduce pumping rate to the amount of storage that is available
82		Duck Lake pumping adjustments: Excess above maximum elevation	If lake storage goes above maximum specified in input, increase pump rate (up to maximum rate) to keep below maximum elevation.
82a		Additional canal spill for storage deficit	If Duck Lake falls below minimum allowable elevation, increase canal spill.
83		Duck Lake pumping adjustments: total	Total Duck Lake pumping rate
84		OID groundwater sale	Amount of groundwater sales from Duck Lake, fixed based on input data
85		Seepage loss	Amount of seepage lost from Duck Lake. Based on seepage curve in input data (developed from historical data)
86		Total outflow	Total outflow from Duck Lake, including pumping, groundwater sale and seepage
87		End storage	End-of-month storage in Duck Lake
88		Elevation	End-of-month Duck Lake elevation, based on interpolation of storage-elevation curve in input data
89	Increase diversion for no Shellrock during spill; decrease for increased Duck pumping	Shellrock pumping	Shellrock pumping rate from column (47)
90		Spill during year?	Flag that tells if spill occurs during the year. Resets to zero each January.
91		Reduced Shellrock pump	If input is set to "Yes" and spill during year flag is "1", Shellrock pumping stops for remainder of year. Results in additional Salmon Creek diversion.
92		Increased Duck Pump	Adjustments to Duck Lake pumping, equal to difference between actual pumping and that initially assumed. Usually results in less Salmon Creek diversion.
92a		Increase canal spill only for Duck Lake deficit	If Duck Lake falls below minimum allowable elevation, increase canal spill. From column (82a).
93		Change to diversion without losses	Total change to diversion due to adjustments in columns (91) and (92).
94		Change in conveyance loss	From column (93), the amount of increased or decreased canal conveyance loss
95		Change in canal spill	From column (93), the amount of increased or decreased canal spill
96		Change to diversion with losses	Sum of column (93) + (94) + (95)

**Attachment Table C-3. Model Supply Model Parameters
Not Modified from 1999 Phase 1 Report (Dames and Moore)**

Column Number	Category	Parameter	Description
97	Increase diversion for no Shellrock during spill; decrease for increased Duck pumping (cont'd)	Revised Salmon Creek diversion	Sum of column (96) + (69)
98		Revised canal loss	Column (94) plus column (71)
99		Revised conveyance loss (spill)	Column (95) plus column (72)
100		Change in canal spill; return back to Duck Lake	Adjustments to spill to Duck Lake, returned to Duck Lake in the following month in column (76)
101		Change in canal diversion; return back to Conconully	Adjustments to canal diversion from Salmon Creek, returned to Conconully Reservoir in the following month in column (35)
102	Salmon Creek Flows	Flow above weir	Middle Reach flow, equal to reservoir release plus spill plus Middle reach gain/loss
103		OID irrigation diversion	Diversion from Salmon Creek to OID canal, equal to column (97)
104		Flow below weir	Lower reach flow below diversion, equal to column (102) minus column (103)
105		Flow at Watercress	Lower reach flow at Watercress springs, equal to column (104) minus reach loss specified in input data for upper portion of lower reach
106		Flow at Mouth	Lower reach flow at mouth, equal to column (105) minus reach loss specified in input data for lower portion of lower reach
107	Okanogan River Flows	Above Shellrock	Historical Okanogan River flows above Shellrock, from time series input. Based on Malott USGS flows adjusted for regulated Salmon Creek and Shellrock Pump flows as estimated from Existing Condition model
108		Shellrock to Salmon Creek	Column (107) flows minus Shellrock pumping, as estimated from Existing Condition model
109		Salmon Creek to Malott	Column (108) flows minus Salmon Creek at mouth flows, as estimated from Existing Conditions model
110	Total Irrigation Delivery	Salmon Creek diversion	From column (103)
111		Canal seepage loss	From column (94)
112		Canal conveyance loss (spill)	From column (95)
113		Duck Lake pumping	From column (83)
114		Shellrock pumping	From column (89) minus column (91)
115		Critical period shortage	From column (19)
116		New Okanogan River pumping	From column (70)
117		Total Irrigation Delivery	Sum of columns (110) to (116)